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Is Nuclear Energy the Answer to India's Growing Energy Needs?

The sustainable development of human societies has invariably depended on energy resources. With the ever increasing population and industrial growth, the demand for energy resources has increased many folds globally. India with its current population of about 1.394 billion is also struggling to fulfill its energy needs and mostly depends upon imports of about 87% of its energy requirements. India being a continent size country with huge potential of land and oceanic natural resources is by and large unexplored. With its 26 mega sedimentary basins having proven and potential natural energy resources, the country is not in a position to meet the domestic energy requirements indigenously. Accordingly to the 'National Geographic' report presently India uses 320 billion kilowatt-hours of energy every day. Most of this energy requirement is met by burning fossil fuels. Although burning of fossil fuels have catered to our energy needs very efficiently, but they are also non-renewable and rapidly depleting on the one hand and are detrimental for climate change and global warming. These fuel sources have immensely contributed to greenhouse gas emissions and pollution. Need of the hour is to find suitable and better replacements for these natural energy resources. India has been constantly researching newer and greener sources of energy which are environment friendly and have less impact global warming. Some of the cleaner and greener energy resources which have potential to cater India's energy demand are atomic energy, solar energy, hydropower, and energy from wind and bio fuels which are promising alternatives to the existing fossil fuels. Other relatively new sources of energy which are being explored include fuel cells, geothermal energy, and ocean energy.

At present fossil fuels account for 86% of the total energy produced in the world of which petroleum accounted for 36.8%, coal 26.6% and natural gas 22.9% (according to the estimates by the Energy Information Administration). Indian energy scenarios also fit well within these estimates which need to be addressed earnestly because our heavy dependence on fossil fuels results in carbon dioxide produced during combustion which amounts to 21.3 billion tons per year. In contrary of producing carbon dioxide, the natural processes are capable of absorbing only about half of the total amount of carbon dioxide emissions released into the atmosphere. Thus every year the amount of carbon dioxide in the atmosphere is increasing by 10.65 billion tons, which is considered as the leading contributor to global warming that potentially impacts very adverse effects on the ecosystem. Natural gas is another major source of energy in use. It is being considered as cleaner than other fossil fuels, but still been found to contribute to pollution and global warming and it is not fully clean, non-polluting alternative to fossil fuels. According to the estimates made in 2004, carbon dioxide emissions due to the use of natural gas amounted to 5,300 million tons while use of coal and oil contributed to carbon dioxide emissions of 10,600 and 10,200 million tons respectively. It has been estimated that in 2030, natural gas is likely to emit 11,000 million tons of carbon dioxide and 8,400 million tons from coal and 17,200 tons from oil. Natural gas when released directly into the atmosphere is a far more potent greenhouse gas than carbon dioxide. In such a scenario the better option is to concentrate exploring other energy options which are environment friendly and do not impact adversely on global warming and ecosystems. One of such options is to directly tap energy from the Sun which has unlimited source of energy. The earth receives about 174 billion megawatts of power at the upper atmosphere as a result of solar radiation. About 30% of the incident solar radiation is reflected back, while about 3.85 x 1024 Joules every year, is absorbed by the atmosphere, oceans and landmasses. The amount of solar energy available during an hour is more than the total amount of energy consumed worldwide during an entire year. The greatest challenge lies in harnessing this energy because this is a diffused form of energy. Other challenge of harnessing the solar energy is building cost effective solar panels/storage of energy, lacking of which at the moment costs about 3 folds higher as compared to the cost of the coal-based power per kilowatt/hour. Unless we perfect the solar harnessing technology and store solar energy in a viable and cost-effective manner, fossil fuels will continue to dominate the source of energy used and further deteriorate the environments and the ecosystems.

Perhaps a viable solution to the enegy crisis of our times lies in nuclear energy even though this kind of energy is also marred by number of challenges. However, with surge in demand for power, nuclear energy is gaining increasing importance as a clean source of power which is also likely to address the global issue of climate change. At present the nuclear power reactors operational in 30 countries around the world account for 14% of the total power generation of the world. The International Atomic Energy Agency (IAEA) expects the global nuclear power generation capacity to increase to 473–748 GW by 2030 from 437–542 GW in 2020. In spite of the fact that nuclear energy gains importance, it faces several challenges in emerging as a reliable and clean source of energy. The important one that needs immediate attention include improvement in economic competitiveness, designing safe and reliable nuclear power plants, management of disposal of radioactive waste, raising public confidence in nuclear power, and ensuring nuclear non-proliferation and security. In the process of harnessing nuclear energy usually in 'nuclear fission' uranium is used. At the current rates of consumption, the uranium reserves discovered in the Earth's crust can last for about 100 years. As per available research trends, the energy consumption will increase 3 fold during the next 100 years, which means that the available uranium resources will only last for approximately 30 years. The option of reprocessing of used uranium (residue rich in plutonium and left over uranium) can stretch the available uranium resources by a few decades more.

The main source of electricity generation in India is coal, gas, hydroelectricity and wind power. Nuclear power is the fifth important source of energy. As of November 2020, India had 22 nuclear reactors in operation in 7 nuclear power plants, with a total installed capacity of 6,780 MW. Nuclear power produced a total of 35 TWh which formed 3.22% of country's electricity supply in 2017. Seven more reactors were under construction with a combined generation capacity of 4,300 MW. India has small uranium reserves and the country is dependent on uranium imports to fuel its nuclear power plants. Since early 1990s, Russia has been a major supplier of nuclear fuel to India. Due to dwindling domestic uranium reserves, electricity generation from nuclear power plants in India declined by 12.83% from 2006 to 2008. In September 2008, the Nuclear Suppliers Group (NSG) permitted a waiver to India enabling her to sign bilateral deals on civilian nuclear energy technology cooperation with several other countries and import nuclear fuels. Kazakhstan was the largest supplier of uranium to India providing 5,000 tonnes during 2015-19. With concerted efforts by the geoscientists of the country, in March 2011 large deposits of uranium were discovered in the Tummalapalle belt in Andhra Pradesh and in the Bhima basin in Karnataka by the Atomic Minerals Directorate for Exploration and Research (AMD) of India. The Tummalapalle belt uranium reserves is one of the best 20 uranium reserves discoveries of the world. So far 44,000 tonnes of natural uranium have been discovered in the region. The natural uranium deposits of the Bhima basin are better grade of natural uranium ore as compared to the Tummalapalle belt.

On the other hand nuclear fusion could be the solution to the current energy demand. Fusion utilizes hydrogen isotopes, lithium, and boron. The estimated lithium reserves from the earth and the sea can last for more than 60 million years. Deuterium, an isotope of hydrogen, can last another 250 million years. At the moment, the process of harnessing energy from this Deuterium isotope is very complicated and the process is in its infancy. It is expected that on acquiring knowledge how to utilize nuclear fusion (a clean process with low carbon dioxide emission and relatively short half-life) for the generation of energy in a viable manner, it could solve energy crisis of the world. These discoveries and their exploitation are likely to lessen the import of nuclear fuel and shall increase nuclear power generation in India in the near future. In recent years, India has shown increased interest in thorium fuels and fuel cycles because of large deposits of thorium (518,000 tonnes) in the form of monazite in beach sands as compared to very modest reserves of low-grade uranium (92,000 tonnes). In this direction India has been making advances in the field of thorium-based fuels and is working to design and develop a prototype for an atomic reactor using thorium and low-enriched uranium. This forms a key part of India's three stage nuclear power programme conceived under the fusion power area through the ITER initiative. India has reasonably assured resources of 319,000 tonnes of thorium – about 13% of the world total, and these are intended to fuel its nuclear power program for a longer-term. AMD claims almost 12 million tonnes of monazite which might contain 700,000 tonnes of thorium.

The nuclear fusion could also be part of the solution to the current energy demand. Fusion utilizes hydrogen isotopes, lithium, and boron. The estimated lithium reserves from the earth and the sea can last for more than 60 million years. Deuterium, an isotope of hydrogen, can last another 250 million years. At the moment, the process of harnessing energy from this Deuterium isotope is very complicated and the process is in its infancy. It is expected that on acquiring knowledge how to utilize nuclear fusion (a clean process with low carbon dioxide emission and relatively short half-life) for the generation of energy in a viable manner, it could solve energy crisis of the world. India's dependence on imported energy resources and the inconsistent development of the energy sector are the main challenges to meet the increasing energy demand. The 2019 edition of BP's Energy Outlook projected India's energy consumption increasing by 156% from 2017 and 2040. The report also shows the country's energy mix will evolve slowly by 2040, with fossil fuels consumption reducing from 92% in 2017 to 79% in 2040. In actual terms, primary energy consumption from fossil fuels is expected to increase by 120% during this period.

Early in 2019 India was set to achieve 100% household electricity connection but couldn't achieve the target. The OECD's International Energy Agency projected that India will need some $1.6 trillion investment in power generation, transmission and distribution by 2035 including 63 GWe target. However, in March 2018, the government stated that nuclear capacity would fall well short of its 63 GWe target and the total nuclear capacity is likely to be about 22.5 GWe by the year 2031. There are number of reasons to miss the set targets, the major among them appear to be dependence of import of the nuclear fuels and low domestic production.

The most important priority of the government of India is economic growth and to alleviate poverty. This compels the government to generate electricity by burning coal and hydrocarbons. The burning of coal for power generation means that CO_2 emission reduction is not a high priority, and the government declined to set targets ahead of the 21st Conference of the Parties on Climate Change held in Paris in 2015. "The environment minister in September 2014 said it would be 30 years before India would be likely to see a decrease in CO_2 emissions". The geosciences fraternity of India is whole heatedly making efforts to explore more and more regions/basins of the country for nuclear energy fuels. In their pursuit they have been concentrating on newer and unexplored regions of the country. In their endevours during the past few years, exploration activities have been concentrated in the following areasul results with fruits:

- Proterozoic Cuddapah Basin, Andhra Pradesh, and Telangana.
- Mesoproterozoic Singhbhum Shear Zone, Jharkhand.
- Mesoproterozoic North Delhi Fold Belt, Rajasthan & Haryana.
- Cretaceous Mahadek Basin, Meghalaya.
- Neoproterozoic Bhima Basin, Karnataka.
- Proterozoic Kaladgi Basin, Karnataka.
- Paleozoic – Mesozoic Satpura Gondwana Basin, Madhya Pradesh.
- Mesoproterozoic Chhotanagpur Granite Gneiss Complex, Uttar Pradesh, Madhya Pradesh, and Jharkhand.
- Cenozoic Siwalik Group, Himachal Pradesh.
- Proterozoic Aravalli Fold belt, Rajasthan.
- Other potential geological domains are under active exploration such as the: Dharmapuri Shear Zone in the Southern Granulite Terrain, Tamil Nadu; basement rocks of the Cuddapah Basin, Andhra Pradesh; Shillong Basin, Assam; basement crystallines, Arunachal Pradesh; Vindhyan and Bijwar basins, Uttar Pradesh and Madhya Pradesh; Kotri-Dongargarh belt, Chhattisgarh.
- Extensive exploration including ground and heliborne geophysical (ZTEM, TDEM, magnetic and radiometric), ground geological, radiometric and geochemical surveys and drilling are planned in other geological domains of the country that have the potential to host uranium.

India's uranium resources are modest, with 183,600 tonnes of uranium as identified resources in situ, 160,000 tU of this as reasonably assured resources in situ and 23,600 tonnes as inferred resources in situ (to $260/kgU) on January 2015 in the OECD NEA 'Red Book'. In July 2017, 229,499 tU was clamied by the DAE. These are all in a high-cost category, and India expects to import an increasing proportion of its uranium fuel needs. In 2013 it was importing about 40% of uranium requirements. In July 2015 record annual domestic production of 1252 t U_3O_8 (1062 tU) was reported. However, 2015 production was only 385 tU.

Mining and processing of uranium is carried out by Uranium Corporation of India Ltd (UCIL), also a subsidiary of the Department of Atomic Energy (DAE), in Jharkhand near Calcutta. Common mills are near Jaduguda (2500 t/day) and Turamdih (3000 t/day, expanding to 4500 t/day). Jaduguda ore is reported to grade 0.05-0.06%U. All Jharkhand mines are in the Singhbhum shear zone, and all are underground except Banduhurang. Another mill is at Tummalapalle in AP, expanding from 3000 to 4500 t/day. Fracture/fault-controlled uranium mineralisation similar to that in Karnataka in the North Delhi Fold Belt is in the 130 km long Rohil belt in Sikar district in Rajasthan, with 6133 tU identified (March 2014). AMD reports further uranium resources in Chattisgarh state (3380 tU), Himachal Pradesh (665 tU), Maharashtra (300 tU), and Uttar Pradesh (750 tU). In Jharkhand UCIL has a small project to recover uranium from copper tailings, near Hindustan Copper's Rakha and Surda mines.

These above mentioned ongoing and future endevours of exploration and exploitation of nuclear fuel resources in the country shall improve the nuclear power generation in future. The current issue of the JIAS contains 6 articles on the subject which were presented by the geoscientists of AMD and allied research organisations during the 37 Convention of the Indian Association of sedimentologists at AMD, Hyderabad in November 2019.

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